**Center for Fluid Mechanics, Division of Applied Mathematics**
**Fluids, Thermal and Chemical Processes Group, School of Engineering**
**Joint Seminar Series**

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# Living Fluids: Modeling and Simulation of Biologically Active Suspensions


Active particle suspensions, of which a bath of swimming bacteria is a paradigmatic example, are characterized by complex dynamics involving strong fluctuations and large-scale correlated motions. These motions, which result from the many-body interactions between particles, are biologically relevant as they impact mean particle transport, mixing and diffusion, with possible consequences for nutrient uptake and the spreading of bacterial infections. To analyze these effects, a kinetic theory is presented and applied to elucidate the dynamics and pattern formation arising from mean-field interactions. Based on this model, the stability of both aligned and isotropic suspensions is investigated. In isotropic suspensions, a new instability for the active particle stress is found to exist, in which shear stresses are eigenmodes and grow exponentially at low wavenumbers, resulting in large-scale fluctuations in suspensions of rear-actuated swimmers, or pushers, when the product of the linear system size with the suspension volume fraction exceeds a given threshold; no such instability is predicted for head-actuated swimmers, or pullers. Numerical simulations of the kinetic equations are also performed, and applied to study the long-time nonlinear dynamics, which are characterized by transient particle clusters that form and break up in time, as well as complex chaotic flows correlated on the system size. The predictions from the kinetic model are also tested using direct numerical simulations based on a slender-body model for hydrodynamically interacting self-propelled particles. These simulations confirm the existence of a transition to large-scale correlated motions in suspensions of pushers above a critical volume fraction and system size, which is seen most clearly in particle velocity and passive tracer statistics. We also find that the collective dynamics of pushers result in giant number fluctuations, local alignment of swimmers, and strongly mixing flows. Extensions of this work to model chemotactic interactions with an external oxygen field as well as steric interactions in concentrated suspensions are also discussed.